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ABSTRACT

This report details the data requirements and procedures used to develop new school bus routes for Six Mile Elementary School in South Carolina. The project examined the current routes of the school and applied computer based techniques to develop new routes given the existing bus stops. Bus routes were developed so that distance and travel time were minimized. Before the routes could be generated, the map of Six Mile had to be modeled as a network, requiring numerous modifications to fit the heuristics used by the computer program. Using Floyd's Algorithm, the shortest path between every pair of bus stops was computed. The bus stops were clustered into routes, considering the number of children allowed on a bus. A model was developed which estimated the travel time based on a description of the route, and was validated by an actual bus ride through the route. The new routes were evaluated by comparing the time and distance of the old and new routes. The appendix contains a complete description of the seven new routes that were developed, including a listing of all stops and turns the buses must make and the roads the buses are to travel on. Contains numerous tables and figures and 16 references. (KS)

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COMPUTER BASED TECHNIQUES FOR SCHOOL BUS ROUTING

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WP060690

COMPUTER BASED TECHNIQUES FOR SCHOOL BUS ROUTING

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June 1990

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ABSTRACT

The data requirements and procedures used to develop new school bus routes for Six Mile Elementary School are presented in this paper. The bus routes have been developed so that distance and travel time are minimized. Although these routes are not necessarily optimal, they do provide substantial savings over the routes currently in use.

INTRODUCTION

School buses play an important role in the transportation of students in each of the 92 school districts of South Carolina. For the 1988-1989 school year, the state owned 5674 school buses for use in the regular school program. These buses were used to transport 365,073 students over a total distance of 45,650,367 miles per year. This is an average of 73 students and 50.7 miles per day for each bus [11].

Given this information, it is not surprising that there has been considerable interest in finding the best possible way to route a fleet of buses. This interest has prompted much research dealing with this type of problem. A survey of several of the techniques used to solve routing problems can be found in DeVoe [3].

Recently, another such project was commissioned by the state of South Carolina. In conjunction with the project, the bus routes of Six Mile Elementary School came under consideration. The purpose of this paper is to examine the current routes of the school and apply computer based techniques to develop new routes given the existing bus stops. This study will also be used to identify problems that may arise in developing routes for the rest of the state.

The following topics will be presented in this paper. First, background information on Six Mile Elementary School will be given as well as a brief discussion on the bus routes now in use. Following this, the data used to develop the routes will be presented. An analysis of the methods used to route the buses will be given along with a model that was developed to evaluate the travel times of the buses. Finally, comparisons between the new and existing bus routes will be made.

BACKGROUND INFORMATION

The town of Six Mile is located in the west central portion of Pickens County in western South Carolina. Six Mile Elementary School enrolls 585 students of both kindergarten and elementary school age. A description of the current bus routes indicated that 373 of these students ride the buses, and there are seven buses to transport these students to and from the school. The attendance area for Six Mile Elementary, including and surrounding the city of Six Mile, is a rural area of approximately 63 square miles and over 185 miles of road. A map of this area is shown in Figure 1.

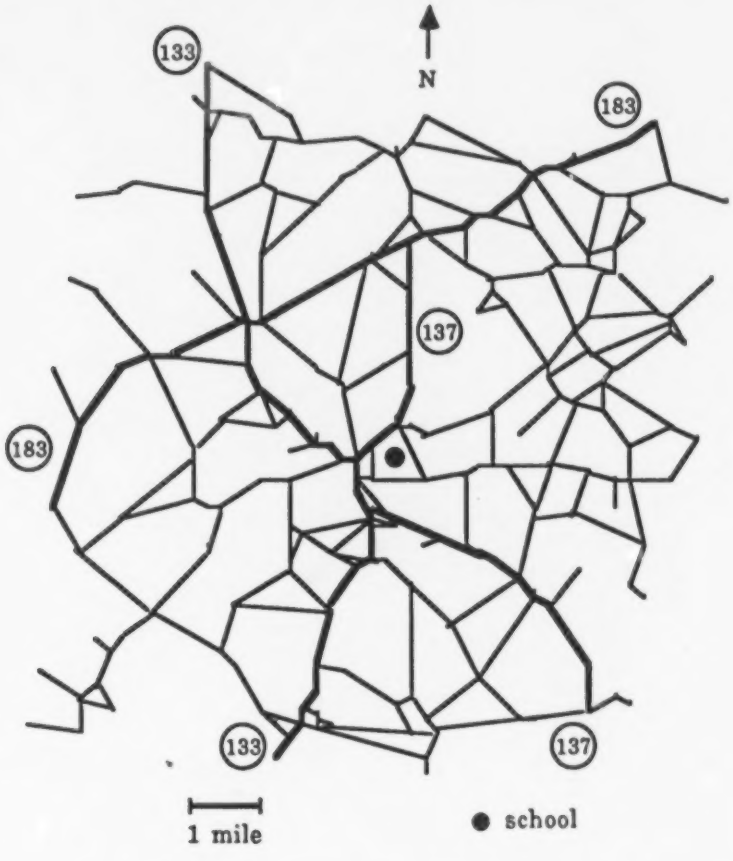

Figure 1. A map of the Six Mile area.

Current Routes

The information given in Table 1, provided by the Pickens County School District Transportation Office, contains a summary of the routes currently being used by the school [13]. The numbers presented are averages since the demand on each bus varies daily — i.e., every child does not necessarily ride the bus every day. However, it is worth noting that the average total distance covered daily is approximately 150 miles. Since

there are approximately 185 miles of road and not every road is used, it seems likely that there are several roads being traversed more than once by the buses. This assumption was justified by a description of the current routes of the buses obtained from the Pickens County School District Transportation Office. Figure 2 gives an indication of the configuration of these routes. The overlap of these bus routes indicates that it is possible to make improvements.

Table 1. Summary of current route information.

route	distance (in miles)	time (in minutes)	children
1	17.9	55	58
2	19.5	65	58
3	29.0	90	60
4	23.5	60	58
5	24.0	85	58
6	16.0	60	58
7	20.0	75	50

Before a meaningful examination of the routes is possible, it is necessary to understand the criteria that the buses and the associated routes must meet. The state has set up the following guidelines [12].

1) Each bus may carry a maximum of 60 children.

2) The maximum time a child may ride on a bus is 75 minutes.

3) Bus stops must be at least one tenth of a mile apart.

In addition, Six Mile Elementary has had to place further restrictions on the routes [15]. Due to the history of rowdiness in one group of children on Love and Care Road, these children must be separated. This makes it necessary to send two or more buses down this road. Also, the children are distributed over the seven buses as evenly as possible. These constraints have resulted in less efficient bus routes.

While the current bus routes meet the required criteria, over the years incremental changes in these routes have produced some characteristics which could be improved. In many cases, two or more buses pick up or drop off children on the same segment of road. Also, some of the routes call for the buses to turn around unnecessarily on roads that are not dead ends. Most of the buses are near capacity, but the travel times and mileage covered vary greatly from bus to bus. Therefore, improvements can be made in several areas.

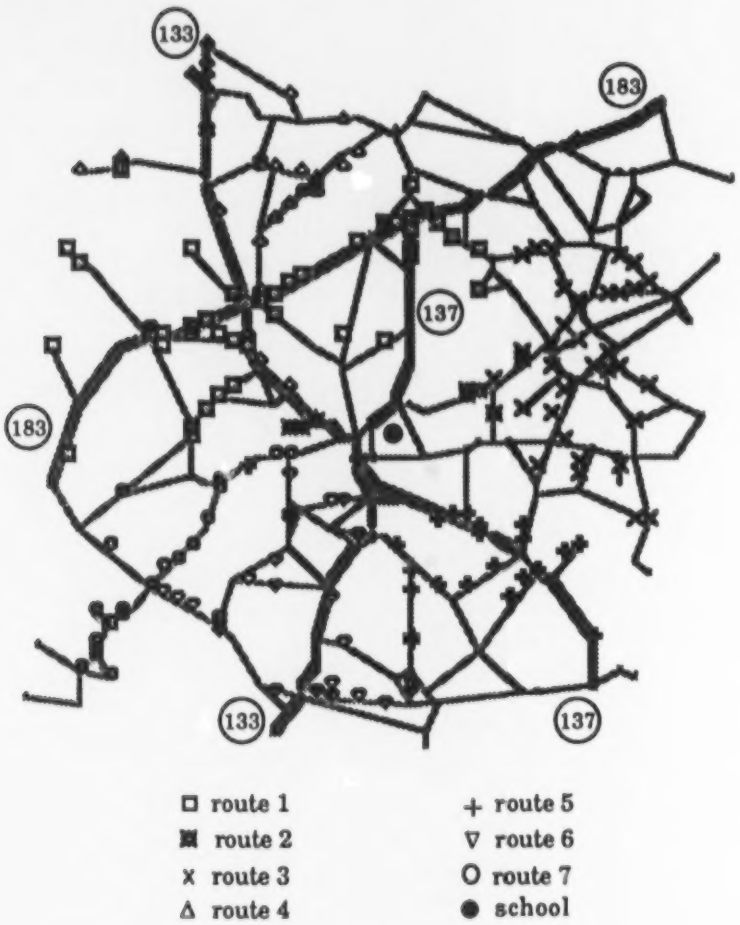

Figure 2. The current bus routes for Six Mile Elementary School.

The Underlying Problem

The idea behind routing buses is simple. Two possible criteria to consider when routes are being developed include:

1) Each stop must be visited exactly once.

2) The miles of road covered should be minimized.

Although the idea is simple, the underlying mathematical problem is very difficult. The problem of finding a route that traverses a set of roads and visits each bus stop exactly once is analogous to finding a Hamiltonian circuit in a graph. To determine whether such a circuit exists is an NP-complete problem [9]. The traveling salesman problem (TSP), which finds a Hamiltonian circuit of minimum total length in the complete graph generated from the original graph, is also NP-complete [9]. This is the problem that must be solved to find an optimal set of bus routes. As of 1985, the largest TSP problem with no special

structure that had been proven to be solved contained 318 nodes [6]. Problems that contain a substantial number of nodes may use such a large amount of computer time that the optimal solution cannot be found. Due to this, heuristic procedures that are not guaranteed to give optimal solutions must be used.

The task of developing routes for buses can be accomplished in several ways. Many schools choose to develop their routes by hand. This method can produce very good routes, but the quality of the routes is usually dependent upon the experience of the scheduler [8]. The method that was used to develop new routes for Six Mile Elementary School was computer assisted, and was based on heuristics for solving the traveling salesman problem.

Most of the heuristics developed to solve routing problems for more than one bus fall into one of two categories. The idea that is common to the first category is to allow a bus of infinite capacity to traverse the bus stops. Once a good route has been found, the route is then partitioned into smaller routes that meet bus capacity and travel time constraints. A successful implementation of this has been accomplished by Bartholdi and Platzman for Meals on Wheels of Atlanta, Georgia [2]. They used a spacefilling curve heuristic to find the route that was to be partitioned. This procedure, although easy to understand and simple to execute, is better suited for an urban area.

The routes that are included in the second category are formed by first partitioning or clustering the stops and then creating routes for each cluster. To determine the routes, a TSP problem for each cluster must be solved. This is the method that was chosen to be implemented for the Six Mile Elementary School routes.

DATA REQUIREMENTS

Before the routes could be generated, there were certain data requirements that had to be met. The most important requirement was, once the data had been collected, that it be formulated in a way so that the heuristics for the traveling salesman problem could be directly applied. Therefore, it was necessary to model the map of Six Mile as a network. In this setting, the intersections of the roads became nodes and the road segments became the edges of the network. The bus stops were then added to the existing network as additional nodes, which in some cases required splitting up an edge into two or more edges. The length of the road segment became the weight of the corresponding edge in the network. Therefore, to model the area of Six Mile as a network it was necessary to know where the intersections of the roads occurred and the length of each road segment. The location of each bus stop was also required.

Data Representation

When the project was begun, the only data available were the 1988-1989 bus routes and a copy of a map of the Six Mile area that was provided by the Pickens County Emergency Preparedness Office (911). This map made the locating of intersections relatively easy; however, calculation of the distances of the roads was not quite as simple. In an attempt to develop coordinates for the intersections and eventually make it possible to calculate distances, the map was digitized and stored as a bit map image. Before any further work was done toward creating the network, the digitized map was "cleaned up". This involved erasing streams, geographical markings, etc. that cluttered the picture. Certain roads on this map had very small distances, and since a bus route would not include them they were deleted from the map. A portion of this digitized map is displayed in Figure 3.

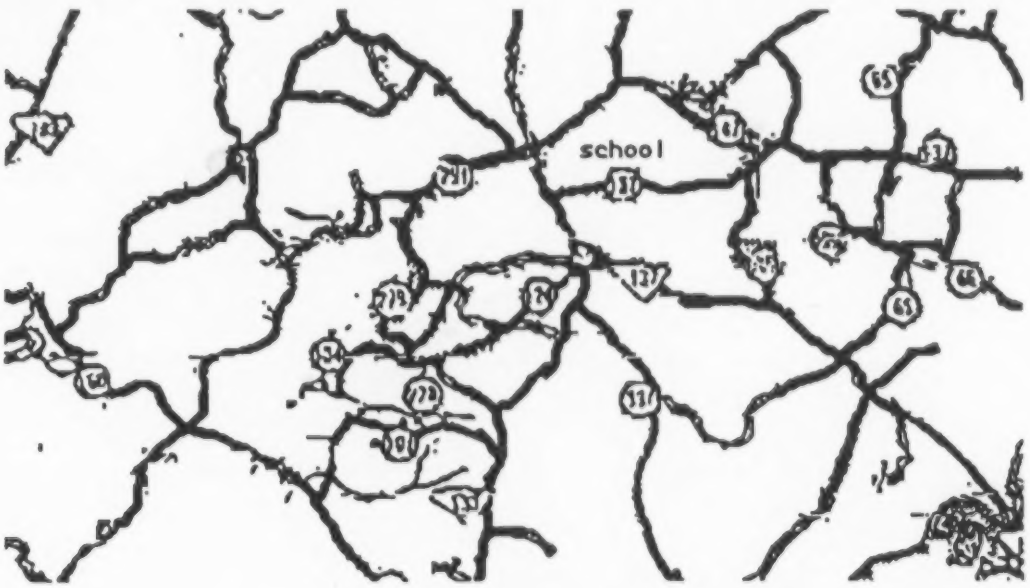

Figure 3. A portion of the digitized map of Six Mile.

The pixel locations of each intersection were then recorded so that eventually the distance of each segment of road could be calculated. This procedure for locating intersections proved to be inefficient and inaccurate, resulting in considerable error. Since the distances would be calculated from the pixel locations, this data would also contain considerable error. Therefore, another representation of the map was required which would provide a more efficient and accurate procedure.

An alternative representation was created using the TIGER files [14] obtained from the U.S. Census Bureau and a program written to display these files [5]. These files contained a list of all of the road segments of the Six Mile area. The segments are continuous, but their endpoints are not necessarily intersections; furthermore, all intersections are endpoints of some road segment. Of the information present in the TIGER files, the following would be used for the development of the routes:

1) a record number that identifies the road segment,

2) a code denoting the type of road (state, county, etc.), and

3) the longitude and latitude of the endpoints of the road segment.

To give a more precise picture of the map, some road segments also had intermediate points, called shape points, associated with them. These shape points were used to indicate the curvature of the road segment and to produce a more accurate calculation of its length. This resulted in a more accurate display of the map.

Creating the Network

The network formed from this data set contained 822 segment endpoints and 1331 segments. Heuristics used to solve traveling salesman problems are usually applied to networks that are complete — i.e. each node has an edge joining it to every other node. In order to apply these heuristics, the shortest path distances between each pair of nodes was needed. To compute these distances for a network of 822 nodes would require considerable computer time, and there would be substantial storage space needed since information about 337,431 edges would have to be kept. Thus, it was necessary to reduce the number of nodes and edges if possible.

The map created from the TIGER files was examined to see if any roads could be deleted. Deleting a road segment would result in the deletion of at least one edge and possibly one node in the corresponding network. In an attempt to reduce the size of the network, a decision was made to delete all roads on this map that did not appear on the 911 map and dead end roads which currently had no bus stops.

While this greatly reduced the size of the network, more simplification was possible. It was discovered that in some cases two or more road segments in the TIGER files could be represented as one road segment, so the place where these segments met would appear as a degree two node. By merging the road segments that met at a degree two node, the corresponding network would be reduced by one node and one edge. The problem of degree two nodes was compounded when road segments were deleted as

described above. For example, consider the section of the map shown in Figure 4. Road a is a dead end road which has a small distance and does not contain a bus stop. Also, roads a, b, and c do not appear on the 911 map, and node 4 is a degree two node. Thus roads a, b, and c were deleted from the map, creating three more degree two nodes — i.e. nodes 2, 3, and 5. Ideally, the section of highway 183 between intersections 1 and 6 should be listed as only one road segment with four shape points, not five separate road segments.

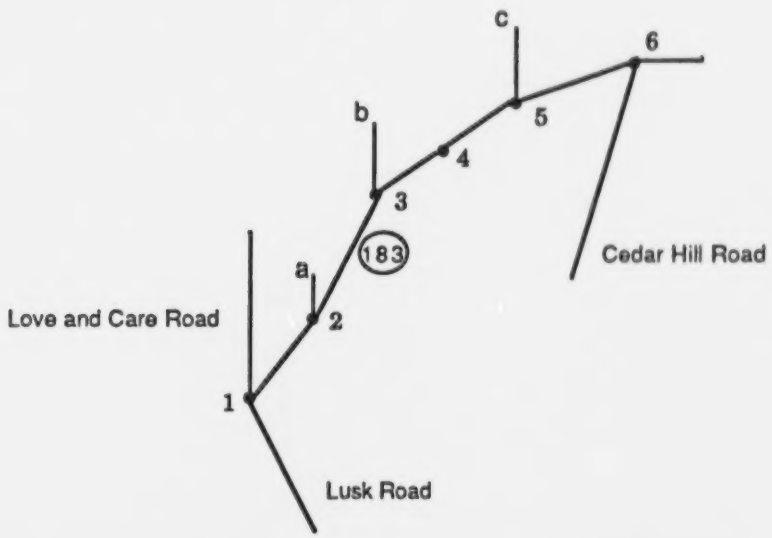

Figure 4. A portion of Highway 183 represented as five road segments.

To avoid having to locate each degree two node by hand, a systematic way had to be developed to locate and change these nodes to shape points. The information from the TIGER files was imported into a database, making it easier to locate the degree two nodes and merge the two adjacent segments. The node that was of degree two was then changed into a shape point for the new segment. Continuing with the example from Figure 4, after the degree two nodes were deleted, the segment of highway 183 would appear as shown in Figure 5. Here nodes 2, 3, 4, and 5 have become shape points for the road segment from intersection 1 to intersection 6. Once this process was completed for all degree two nodes, the resulting network contained 371 nodes and 483 edges.

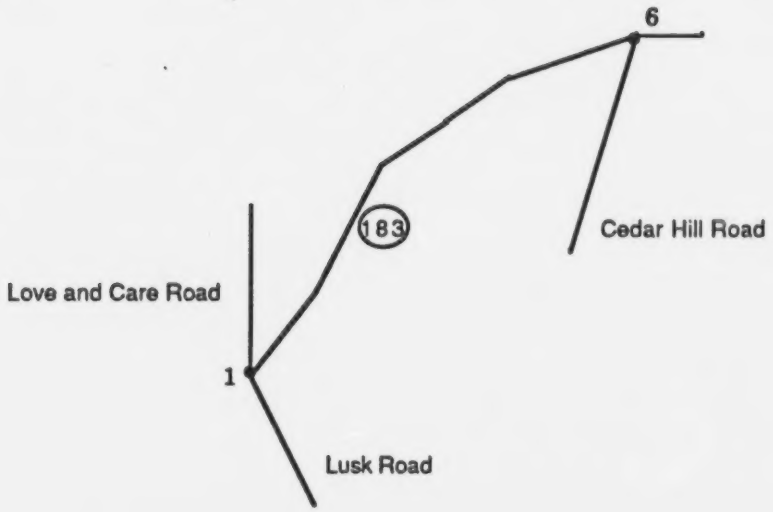

Figure 5. The same portion of Highway 183 represented as one road segment.

DEVELOPING THE ROUTES

To implement the clustering routine and then determine the final routes, the shortest path distance between every pair of bus stops was needed. To accomplish this, the distance of each road segment was calculated using straight line distances and the associated shape points. An edge list was then created for the resulting network. This list would then be used to compute the shortest path between every pair of nodes in the network. Once this information was computed, the actual routing of the buses could begin.

To create the edge list, it was necessary to have the endpoints of the edges correspond to nodes in the network — these nodes would consist not only of the intersections, but also the bus stops. These intersections and bus stops were numbered, which required locating the bus stops on the 911 map. The network now contained 413 nodes and 484 edges. An edge list was then created that contained the endpoints and associated distance for each edge. Using Floyd's Algorithm [16], the shortest path distance between every pair of nodes in the network was computed. The distances of interest were the shortest paths between every pair of bus stops.

Clustering

Now that the shortest path information was available, the bus stops could be grouped. The first step was to apply a hierarchical clustering routine which clustered based on the shortest path distance between pairs of bus stops [1]. The technique employed was agglomerative, so at each step two clusters were joined to create a new cluster [7]. This process continued until all points were contained in a single cluster. Due to the rule used to combine the clusters, the number of bus stops in each cluster varied considerably. Since each bus stop represents one or more children that must be transported, a cluster that contains 50 bus stops might represent over 60 children. This made it impossible to use directly the grouping containing the exact number of clusters needed. For example, consider Table 2 that shows the information of the grouping containing seven clusters. Clearly, several of these clusters do not meet the capacity constraints of the buses. The set of clusters which proved to be the easiest to work with was one containing 14 clusters. These clusters would be combined to produce the seven clusters which would make up the routes.

Table 2. Information on grouping containing seven clusters.

cluster	number of bus stops	number of children
1	26	58
2	51	101
3	45	79
4	33	62
5	21	52
6	9	13
7	2	8

It was crucial to insure that the final clusters would not violate the capacity constraints of the buses, since the clusters formed would be used to generate the bus routes. In addition to being able to view the clusters, information such as which cluster a particular bus stop was in and the number of children to be picked up needed to be easily accessible. This made it necessary to create another representation of the map that also displayed the bus stops; an estimate of the longitude and latitude coordinates for each bus stop was required. The set of 14 clusters was then displayed and seven clusters were generated which met the required guidelines.

Routing the Buses

With the clusters determined, only the actual routing of the buses remained. To accomplish this, the complete graph associated with each cluster was needed in order to apply the heuristics for the traveling salesman problem. The distance between every pair of bus stops in each cluster was then found using the shortest path information previously computed. Each complete subgraph was then converted into an edge list format. Since the desired solution for the traveling salesman problem was the shortest route from the origin of the bus route to the school, these locations were added as two additional nodes to each subgraph. Then, for each route, edges were added that joined the origin of the route to a few of the nearest bus stops, as well as edges joining the school to a few bus stops which were closest to it. Figure 6 shows the edges that would be added for a particular cluster of bus stops. These edges and their associated distances were then added to the appropriate edge list.

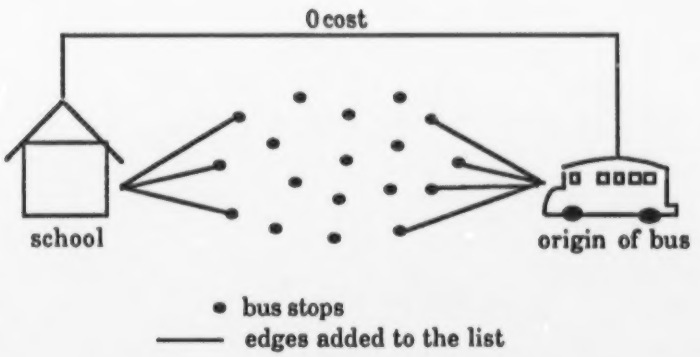

Figure 6. The edges added from the origin and school to a cluster of bus stops.

A variety of heuristics used to solve the traveling salesman problem were then applied to the edge lists. These heuristics were: cheapest insertion, nearest insertion, farthest insertion, nearest neighbor, and ordinal insertion. A complete discussion of these heuristics can be found in Golden, et al. [4].

For every cluster, each heuristic was run to determine which method gave the route of minimum distance. In most cases, the variation between the routes created by the different heuristics was minimal — usually this distance was less than one mile out of an average distance per route of 18.02 miles. While these heuristics provided for minimum distance, they did not consider factors that contribute considerably to travel time, such as the number of times a bus must turn around on a route. Thus it was necessary to manually examine each route. If an improvement could be made, the route was modified accordingly. If, however, the route with minimum distance required too many changes, the route with the next smallest distance was examined. Also, to insure that the time the children rode the bus was minimized, they were picked up the last time a segment of road was traversed. Once this process was completed, the routes were ready to be evaluated.

TRAVEL TIME MODEL

As mentioned earlier, the time that it takes to complete a route is an important criteria when routing buses. Since the distances that the buses travel on each route were known, as well as the number of stops and turns each bus made, a way to use this information to predict travel times for the buses was needed. A model was developed which estimated travel time based on a description of the route. Once these travel times were found, the model had to be validated before any conclusions could be drawn about the new routes. The distances and travel times for the old and new routes were then compared to determine if an improvement had been made.

Development of the Model

Collecting the data to develop the travel time model entailed riding on one of the Six Mile Elementary School buses during both the morning and afternoon routes. The route used to develop this model was route 5. The information obtained was the following:

1) travel time and associated distance,

2) time to pick up and drop off children along with the number of children at each stop,

3) time for the bus to turn right or left, and

4) time for the bus to turn around.

Each of these types of data was evaluated, using various methods of statistical analysis, to develop four separate models. These models would be used in conjunction to predict the travel times for both the new and current routes.

The method of collecting the data for the model was simple. When the bus began moving, this time and the odometer reading were recorded. The time and corresponding distance were recorded when the bus came to a complete stop. If the bus stopped to pick up or drop off children, this time was recorded from the time the bus stopped until the bus began moving. If the bus made a turn, the time was recorded from the time the bus either stopped or began turning until the turn was completed. For the bus to turn around, the time was recorded from the time the bus began reversing until the time it pulled back onto the road.

For the travel times and distances, 75 observations were recorded. Regression analysis was done using distance as the independent variable and time as the dependent variable. This analysis involved both simple and polynomial regression, along with transformations of both the dependent and independent variables. Usually when modeling distance versus travel time, the type of model expected is one where time is disproportionately large for small distances and then becomes proportional to distance. The first few models obtained did not fall into this category, partially due to the effect of outliers in the distance data. After restricting the distances used in the analysis to those of one mile and less, 69 observations were left to analyze. The linear model had an R^2 value of .708, but did not have the expected form. On the other hand, the polynomial

model gave an R^2 value of .723, which indicates a fairly good fit for the data, and also yielded the correct form. This model, shown in Figure 7, was the one chosen to be used in the travel time analysis.

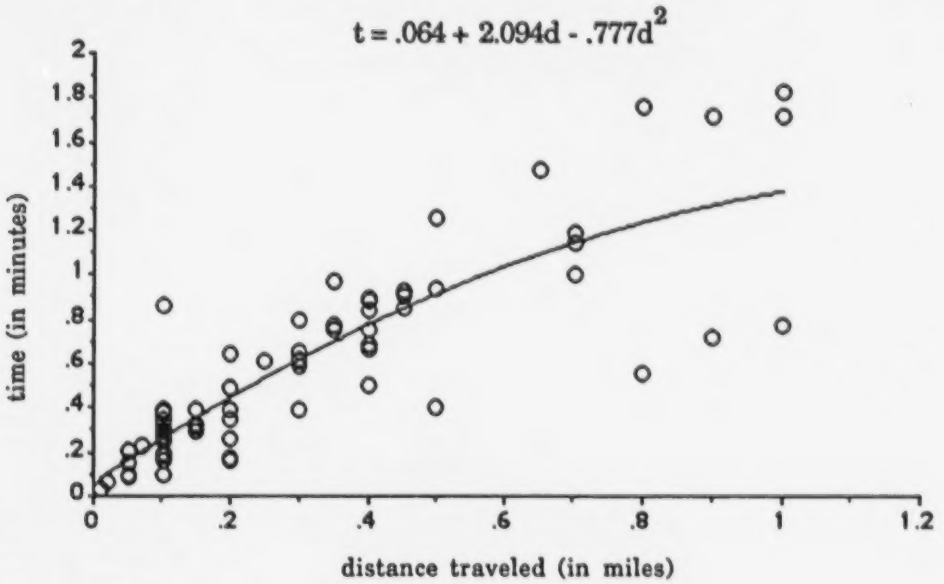

Figure 7. Model for distance versus time.

For the times the bus turned right or left, five observations were recorded. Since this was the sole variable in this model, the only value needed was the mean, which was .167 minutes. This value was then used in evaluating the routes.

Finally, seven observations were recorded for the times the bus takes to turn around. Again, since this was the only variable involved, the data needed to develop this model was the mean. This value was .475 minutes, which was then used to evaluate the routes.

For the pick up and drop off times, 36 observations were recorded. Regression was done using the number of children picked up or dropped off as the independent variable and time as the dependent variable. Again after trial and error, the linear model shown in Figure 8 was chosen. This model gave an R^2 value of .708, which indicates a fairly good fit. Other factors not taken into account when analyzing this data but which might affect the model include where the children's assigned seats were in relation to the front of the bus, where the children lived in relation to the side of the street on which the bus stopped, and the amount of time the children spent talking to the bus driver at each stop. This model, however, was the one chosen to be used in the travel time analysis.

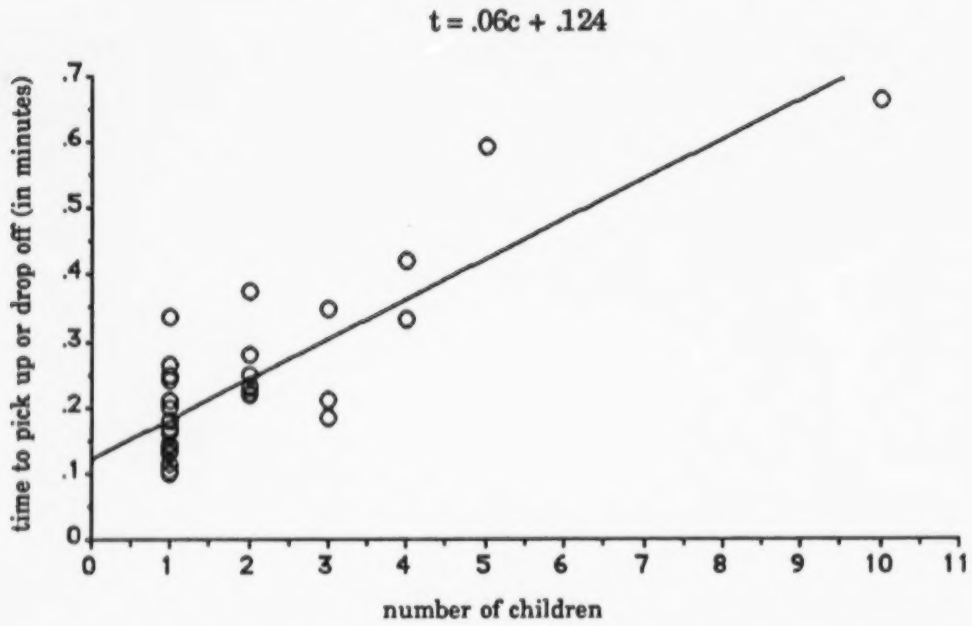

Figure 8. Model for number of children versus time to pick up or drop off.

These four statistical models were then combined to produce a travel time estimate for each route, given a description of the route which contained the appropriate information.

Validation of the Model

With the travel time model developed, it was necessary to validate it by computing the travel time for an existing route, other than the one used in developing the model. The route used to validate the model was route 6, although the route the bus driver followed when observed did differ from the description of route 6 which had been provided. Once again, this entailed riding the bus and obtaining the same information which had been used to construct the model. This data was used to form a description of the route, which was used by the model to compute a travel time estimate. This estimated travel time was 43.8 minutes, while the actual travel time was 52.1 minutes — a difference of 8.3 minutes. One reason for this discrepancy could be that insufficient data was used in developing the model. Ideally data should have been collected from all the bus routes, but this was not feasible. The model was still used to predict the travel times for the new routes, but the travel times for the current routes were also predicted so that a valid comparison could be made. These times, along with those reported by the school, are given in Table 3. There are several reasons for the differences in the travel times shown for a particular route. The times predicted by the model were based on descriptions of the routes provided at the beginning of the school year. The reported times were provided near the end of the school year, and were average times based on a twenty-day period. For the observed times, the bus driver did not exactly follow the bus route which was given in the description. The predicted times were the travel times used in comparing the travel times for the current and new routes.

Table 3. Travel times (in minutes) for the current routes.

route	predicted time	reported time	observed time
1	75.7	55	—
2	29.9	65	—
3	78.9	90	—
4	50.3	60	—
5	49.8	85	50.5
6	54.1	60	52.1
7	38.3	75	—

EVALUATION OF THE ROUTES

After the travel time model was validated, travel times for the new routes were estimated and compared to those computed for the current routes, along with the corresponding distances. This comparison was then used to decide whether the new routes were an improvement over those currently being used. The travel time estimates for the new routes, along with the other route information, are shown in Table 4.

Table 4: Summary of new route information.

route	distance (in miles)	time (in minutes)	children
1	18.4	54.2	52
2	12.6	35.7	57
3	23.9	56.7	54
4	17.0	49.9	48
5	12.6	40.4	57
6	16.2	43.0	51
7	19.3	36.0	54

Several factors must be taken into consideration when comparing the two sets of routes. First, the new routes were based on information about the current routes which was subject to change over the school year. Also, the distances for the current routes were provided by the bus drivers; the distances for the new routes were computed using the information in the TIGER files. This may cause some discrepancy in the travel times predicted by the model. The comparison will be based on two criteria — the total distance traveled and the total travel time as predicted by the model.

First, to compare the two sets of routes visually, consider Figure 9. In comparing these routes with those for the current routes shown in Figure 2, less overlap occurs in the new routes, and each route is more confined to a particular area. This implies that the new routes should be more efficient than those currently being used, as far as distance and time are concerned. A complete description of the new routes can be found in the appendix.

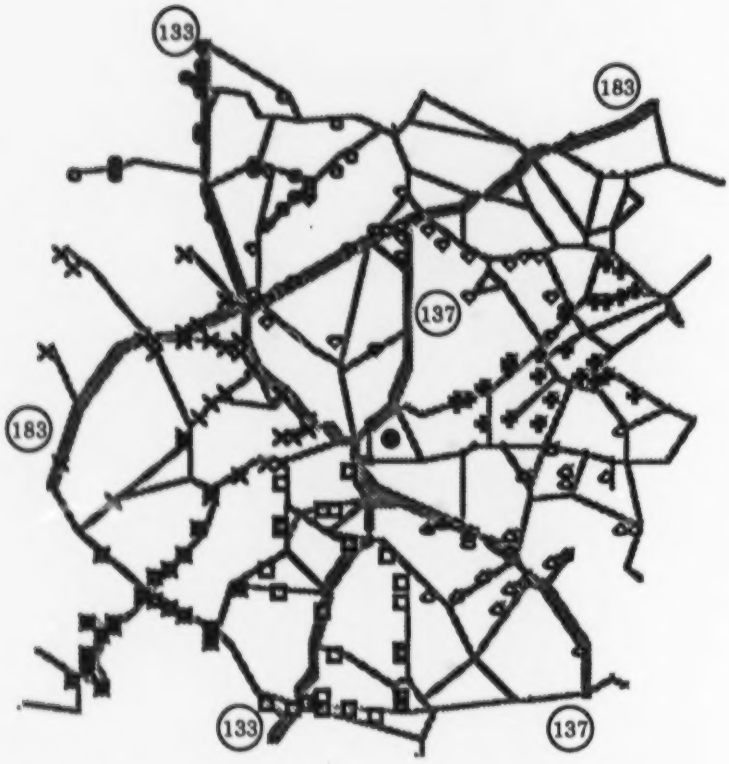

Figure 9. The new routes developed for Six Mile Elementary School.

With each of the new bus routes being more compact, it would be expected that there would be a corresponding savings in the distance traveled. The total distance covered by the current routes on each of the morning and afternoon runs, obtained from Table 1, is 149.9 miles. The distance covered by the new routes, from Table 4, is 120 miles. Thus the new routes would decrease the total distance traveled per run by approximately 29.9 miles, which is an average decrease of 8.54 miles per bus per day. This represents a 20% savings in total distance traveled.

Finally, consider the travel times for the two sets of routes predicted using the model. The total travel time for the current routes on each of the morning and afternoon runs, obtained from Table 1, is 377 minutes. The total travel time for the new routes, from Table 4, is 315.9 minutes. Thus the new routes would cut down on the total travel time per run by 61.1 minutes, or approximately 17.5 minutes per bus per day. The resulting percentage savings in total travel time is 16.2%.

CONCLUSIONS

A new set of routes for Six Mile Elementary School and the work necessary to construct these routes has been presented in this paper. While the routes created by no means provide optimal solutions, it has been shown that they offer considerable savings both in terms of the distance traveled and the travel time. This paper did not consider the effects of changing the bus stops that are currently in use; perhaps by close study and restructuring of these stops even more efficient routes could be developed. In any case, the application of computer based techniques to routing the buses of Six Mile Elementary School has produced new routes that offer the potential for substantial savings.

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APPENDIX

Description of New Routes

The following is a description of the seven routes that were developed. It contains a listing of all stops and turns the buses must make along with the roads the buses are to travel on. These routes are for the morning runs of the buses. For the afternoon runs, the bus routes should be reversed.

Route 1

Distance	Move	Street Name	Number of Children
	start	Cedar Lane Circle	
0.06	right	Norris Highway	
0.60	right	Silver Creek Road	
1.90	right	Maw Bridge Road	
0.32	left	Laurel Road	
0.19	right	Todd's Creek Road	
0.99	stop/right	Sunrise Road	1
0.38	right	Highway 133	
0.56	left	Knollview Road	
0.60	stop	Knollview Road	1
0.00	turn around	Knollview Road	
0.60	right	Highway 133	
0.15	stop	Highway 133	1
1.15	right	Pleasant Hill Church Road	
0.27	stop	Pleasant Hill Church Road	5
0.00	turn around	Pleasant Hill Church Road	
0.27	left	Highway 133	
0.11	right	Red Fox Road	
0.11	stop/left	Horseshoe Road	2
0.18	stop	Horseshoe Road	3
0.20	stop	Horseshoe Road	2
0.20	stop	Horseshoe Road	2
0.20	left	Browning Road	
0.10	stop	Browning Road	1
0.10	stop	Browning Road	3
0.30	stop	Browning Road	1
0.40	stop	Browning Road	2
0.30	left	Todd's Creek Road	
0.19	stop	Todd's Creek Road	3
0.20	stop	Todd's Creek Road	2
0.12	right	Laurel Road	
0.19	left	Maw Bridge Road	
0.30	stop	Maw Bridge Road	1

0.10	stop	Maw Bridge Road	1
0.50	stop	Maw Bridge Road	5
0.20	stop	Maw Bridge Road	1
0.37	stop	Maw Bridge Road	1
0.50	left	Highway 133	
0.16	right	Old Cedar Lane	
0.11	stop	Old Cedar Lane	1
0.30	left	Furman Smith Memorial Highway	
0.38	stop	Furman Smith Memorial Highway	2
0.38	right	Okhateeah Road	
0.15	left	Saluda Circle	
0.55	left	Powder Mill Road	
0.40	stop	Powder Mill Road	1
0.00	turn around	Powder Mill Road	
0.40	right	Saluda Circle	
0.20	stop	Saluda Circle	2
0.35	left	Okhateeah Road	
0.22	stop	Okhateeah Road	2
0.20	stop	Powder Mill Road	
0.05	stop	Powder Mill Road	1
0.20	stop	Powder Mill Road	4
0.65	left	North Main Street	
0.11	stop	North Main Street	1
0.34	right	Highway 137	
0.30	stop	School	

Total Distance =18.36 miles

Total Number of Children = 52

Route 2

Distance	Move	Street Name	Number of Children
	start	Eden Lane	
0.30	stop/left	Highway 291	1
0.10	stop/left	Shemiah	1
0.20	stop	Shemiah	4
0.10	stop	Shemiah	2
0.70	right	Highway 291	
0.42	stop	Highway 291	2
0.05	stop/left	Toby Hills Road	1
0.20	stop	Toby Hills Road	1
0.00	turn around	Toby Hills Road	
0.20	left	Highway 291	
0.25	stop	Highway 291	2
0.10	stop	Highway 291	1
0.03	stop	Highway 291	2
0.30	stop	Highway 291	2

0.05	right	Jones Mill Road	
0.90	stop/right	Stoneybrook Circle	1
0.10	stop	Stoneybrook Circle	2
0.10	left	Jones Mill Road	
0.18	right	Furman Smith Memorial Highway	
0.60	stop	Furman Smith Memorial Highway	3
0.00	turn around	Furman Smith Memorial Highway	
0.50	stop	Furman Smith Memorial Highway	1
0.10	right	Jones Mill Road	
0.50	stop	Jones Mill Road	1
0.10	stop	Jones Mill Road	5
0.20	stop	Jones Mill Road	1
0.80	stop	Jones Mill Road	5
0.00	turn around	Jones Mill Road	
0.80	left	Highway 291	
0.05	stop	Highway 291	2
0.50	stop	Highway 291	2
0.20	stop	Highway 291	2
0.10	stop	Highway 291	3
0.45	stop	Highway 291	8
0.75	stop	Highway 291	2
2.18	stop	Highway 291	
0.08	straight	Highway 137	
0.30	stop	School	

Total Distance =12.59 miles

Total Number of Children = 57

Route 3

Distance	Move	Street Name	Number of Children
	start	School	
0.30	straight	Highway 291	
0.66	stop	Highway 291	1
0.30	stop	Highway 291	3
0.20	stop	Highway 291	1
0.59	stop	Highway 291	1
0.09	stop	Highway 291	1
0.02	right	Stewart Road	
0.25	left	Dan Ross Road	
0.93	stop	Dan Ross Road	1
0.55	right	Jones Mill Road	
0.46	right	Highway 183	
0.40	stop	Highway 183	1
1.74	left	Sue Craig Road	
1.10	stop	Sue Craig Road	1
0.00	turn around	Sue Craig Road	

1.10	left	Highway 183	
0.43	left	Gap Hill Road	
1.40	stop	Gap Hill Road	2
0.00	turn around	Gap Hill Road	
0.20	stop	Gap Hill Road	1
1.20	stop	Gap Hill Road	1
0.00	straight	Gin Shoales Road	
0.20	stop	Gin Shoales Road	1
1.12	right	Shadydale Circle	
0.13	stop	Shadydale Circle	2
0.22	left	Stewart Road	
0.20	stop	Stewart Road	2
0.28	stop	Stewart Road	1
0.20	stop	Stewart Road	1
0.25	stop	Stewart Road	1
0.40	left	Highway 133	
0.37	left	Booger Branch Road	
0.18	stop	Booger Branch Road	1
0.18	stop	Booger Branch Road	3
0.38	stop	Booger Branch Road	2
0.20	left	Highway 183	
0.05	stop	Highway 183	1
0.00	turn around	Highway 183	
0.26	stop	Highway 183	2
0.20	stop	Highway 183	4
0.55	left	Old Keowee Church Road	
1.60	stop	Old Keowee Church Road	1
0.00	turn around	Old Keowee Church Road	
0.10	stop	Old Keowee Church Road	3
0.85	stop	Old Keowee Church Road	2
0.55	stop	Old Keowee Church Road	1
0.10	left	Highway 183	
0.05	right	Highway 133	
0.38	stop	Highway 133	1
0.20	stop	Highway 133	1
0.16	stop	Highway 133	1
0.40	stop	Highway 133	1
0.62	right	Hominey Hills	
0.48	stop	Hominey Hills	2
0.00	turn around	Hominey Hills	
0.10	stop	Hominey Hills	4
0.27	stop	Hominey Hills	2
0.11	right	Highway 133	
0.31	left	Highway 137	
0.30	stop	School	

Total Distance = 23.87 miles

Total Number of Children = 54

Route 4

Distance	Move	Street Name	Number of Children
	start	Kelly Mill Road	
0.24	right	Terrapin Crossing	
0.82	stop	Terrapin Crossing	2
0.38	right	Liberty Highway	
0.24	left	A T Mann	
0.20	stop	A T Mann	1
0.00	turn around	A T Mann	
0.20	right	Liberty Highway	
0.24	right	Robinson Bridge Road	
0.85	stop/right	Pea Ridge Road	2
0.10	stop	Pea Ridge Road	2
0.83	right	Searcy Road	
0.20	stop	Searcy Road	1
0.20	stop	Searcy Road	2
0.15	left	Liberty Highway	
0.20	stop	Liberty Highway	2
0.72	left	Old Blacksmith Road	
0.50	stop	Old Blacksmith Road	1
0.23	right	Kelly Mill Road	
0.30	stop	Kelly Mill Road	3
0.26	stop	Kelly Mill Road	1
0.35	straight	Camp Creek Road	
0.30	stop	Camp Creek Road	6
0.40	stop	Camp Creek Road	1
0.40	stop	Camp Creek Road	1
0.00	turn around	Camp Creek Road	
1.10	right	Norris Highway	
0.25	right	Silver Creek Road	
0.30	stop	Silver Creek Road	7
0.00	turn around	Silver Creek Road	
0.20	stop	Silver Creek Road	1
0.10	stop/right	Norris Highway	2
1.09	stop	Norris Highway	1
0.00	turn around	Norris Highway	
1.35	right	B D Johnston Road	
0.40	stop	B D Johnston Road	1
0.00	turn around	B D Johnston Road	
0.20	stop	B D Johnston Road	4
0.20	right	Norris Highway	
0.54	left	Cedar Lane Circle	
0.03	stop	Cedar Lane Circle	2
0.15	stop	Cedar Lane Circle	2
0.05	left	Norris Highway	
0.10	right	John Holliday Road	
0.08	stop	John Holliday Road	1

0.00	turn around	John Holliday Road	
0.08	right	Norris Highway	
0.10	left	Issaqueena Drive	
0.41	stop	Issaqueena Drive	1
0.10	stop/left	Norris Highway	1
0.94	right	North Main Street	
0.60	right	Highway 137	
0.30	stop	School	

Total Distance = 16.98 miles

Total Number of Children = 48

Route 5

Distance	Move	Street Name	Number of Children
	start	Praters Creek Road	
0.02	stop	Praters Creek Road	1
0.30	stop	Praters Creek Road	1
0.00	turn around	Praters Creek Road	
0.30	left	Stewart Gin Road	
0.50	stop	Stewart Gin Road	3
0.00	turn around	Stewart Gin Road	
0.40	stop	Stewart Gin Road	1
0.32	stop	Stewart Gin Road	3
0.23	straight	Kelly Mill Road	
0.23	stop	Kelly Mill Road	2
0.30	stop	Kelly Mill Road	5
0.30	right	Liberty Highway	
0.60	right	Mimosa Drive	
0.30	stop	Mimosa Drive	7
0.39	right	Belle Shoals Road	
0.81	right	Terrapin Crossing	
0.10	stop	Terrapin Crossing	1
0.32	right	Andrew Road	
0.58	stop	Andrew Road	1
0.00	turn around	Andrew Road	
0.58	left	Terrapin Crossing	
0.10	stop	Terrapin Crossing	4
0.10	right	Watson Road	
0.31	stop	Watson Road	1
0.27	left	Praters Creek Road	
0.28	right	Belle Shoals Road	
0.14	left	Morningside Drive	
0.58	right	St. Philips Street	
0.04	right	Sunset Road	
0.06	stop	Sunset Road	5
0.20	stop	Sunset Road	2

0.20	stop/right	Belle Shoals Road	2
0.40	stop	Belle Shoals Road	2
0.20	stop	Belle Shoals Road	2
0.20	stop	Belle Shoals Road	1
0.29	stop	Belle Shoals Road	2
0.27	stop	Belle Shoals Road	1
0.52	stop	Belle Shoals Road	1
0.10	stop	Belle Shoals Road	1
0.30	stop	Belle Shoals Road	1
0.21	stop	Belle Shoals Road	1
0.10	stop	Belle Shoals Road	5
0.10	stop	Belle Shoals Road	1
0.62	left	Highway 137	
0.45	stop	School	

Total Distance = 12.62 miles Total Number of Children = 57

Route 6

Distance	Move	Street Name	Number of Children
	start	Watson Road	
0.29	left	Praters Creek Road	
0.28	straight	Praters Creek Road	
0.10	stop	Praters Creek Road	1
0.20	stop	Praters Creek Road	1
0.44	left	Hudson Lane	
0.10	stop	Hudson Lane	1
0.10	stop	Hudson Lane	1
0.20	stop	Hudson Lane	1
0.40	left	Terrapin Crossing	
0.33	right	Pilgrim Circle	
0.15	stop	Pilgrim Circle	1
0.35	left	Terrapin Crossing	
0.32	stop	Terrapin Crossing	2
0.20	stop	Terrapin Crossing	1
0.30	stop	Terrapin Crossing	1
0.20	stop/left	Highway 183	1
0.16	stop/left	Highway 137	1
0.20	stop	Highway 137	1
0.20	stop	Highway 137	2
0.10	stop	Highway 137	2
0.91	right	Holliday Road	
0.28	stop	Holliday Road	2
0.57	right	Lusk Road	
0.11	right	Cedar Hill Road	
0.30	stop	Cedar Hill Road	1

0.00	turn around	Cedar Hill Road	
0.30	right	Lusk Road	
1.17	straight	Love and Care Road	
0.50	stop	Love and Care Road	1
0.30	stop	Love and Care Road	1
0.57	stop	Love and Care Road	3
0.10	stop	Love and Care Road	10
0.91	right	Mountain View Church Road	
0.88	stop	Mountain View Church Road	1
0.43	right	Highway 183	
0.36	stop	Highway 183	2
0.10	stop	Highway 183	1
0.10	stop	Highway 183	2
0.25	stop	Highway 183	1
0.50	stop	Highway 183	1
0.10	stop	Highway 183	3
0.10	stop	Highway 183	2
0.20	stop	Highway 183	2
0.00	turn around	Highway 183	
0.06	right	Lusk Road	
0.18	stop	Lusk Road	1
1.98	left	Highway 137	
0.30	stop	School	

Total Distance = 16.18 miles

Total Number of Children = 51

Route 7

Distance	Move	Street Name	Number of Children
	start	Duncan Road	
0.16	left	Love and Care Road	
0.20	stop	Love and Care Road	1
0.20	stop	Love and Care Road	7
0.38	left	Mile Creek Road	
0.25	stop	Mile Creek Road	1
0.49	right	Little Crowe Creek Road	
0.30	stop	Little Crowe Creek Road	1
1.50	stop/left	Highway 133	2
0.75	stop	Highway 133	2
0.61	stop	Highway 133	1
0.32	right	Lakeside Drive	
0.30	stop	Lakeside Drive	1
0.00	turn around	Lakeside Drive	
0.30	stop/right	Highway 133	1
0.45	stop	Highway 133	1
0.10	stop	Highway 133	1

0.50	right	Keowee Baptist Church Road	
3.07	stop	Keowee Baptist Church Road	2
0.00	turn around	Keowee Baptist Church Road	
2.00	stop	Keowee Baptist Church Road	6
1.07	right	Highway 133	
0.52	stop	Highway 133	1
0.00	turn around	Highway 133	
0.30	right	Hunting Hollow Road	
0.60	stop	Hunting Hollow Road	3
0.12	stop/right	Duncan Road	4
0.15	stop	Duncan Road	1
0.28	stop	Duncan Road	4
0.15	stop	Duncan Road	3
0.15	right	Love and Care Road	
0.30	stop	Love and Care Road	8
0.20	stop	Love and Care Road	2
1.00	stop	Love and Care Road	1
0.10	straight	Lusk Road	
2.16	left	Highway 137	
0.30	stop	School	

Total Distance = 19.28 miles

Total Number of Children = 54

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